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 Bock

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(54) **METHOD, APPARATUS, AND SYSTEM PROVIDING AN IMAGER WITH PIXELS HAVING EXTENDED DYNAMIC RANGE**

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 H01L 27/146 (2006.01)
 H04N 5/355 (2011.01)

(52) **U.S. Cl.**
 CPC *H04N 5/243* (2013.01); *H01L 27/14641* (2013.01); *H04N 5/35554* (2013.01)

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 CPC H04N 5/243; H04N 5/35554; H01L 27/14641
 USPC 348/220.1, 221.1, 222.1, 229.1, 230.1, 348/234, 236, 237, 238, 241, 250, 254, 294, 348/296, 297, 298, 362, 363, 364, 312
 See application file for complete search history.

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(57) **ABSTRACT**

The dynamic range of a pixel is increased by using selective photosensor resets during a frame time of image capture at a timing depending on the light intensity that the pixel will be exposed to during the frame time. Pixels that will be exposed to high light intensity are reset later in the frame than pixels that will be exposed to lower light intensity.

15 Claims, 10 Drawing Sheets
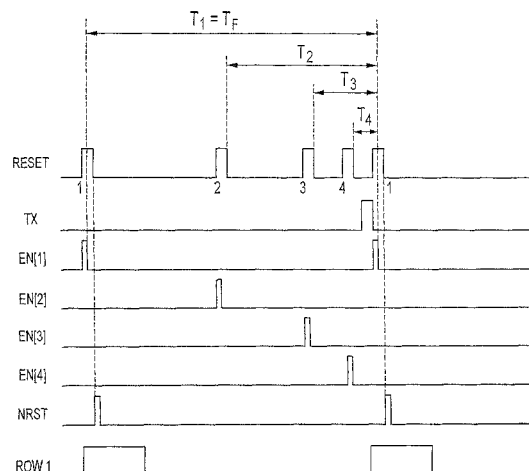
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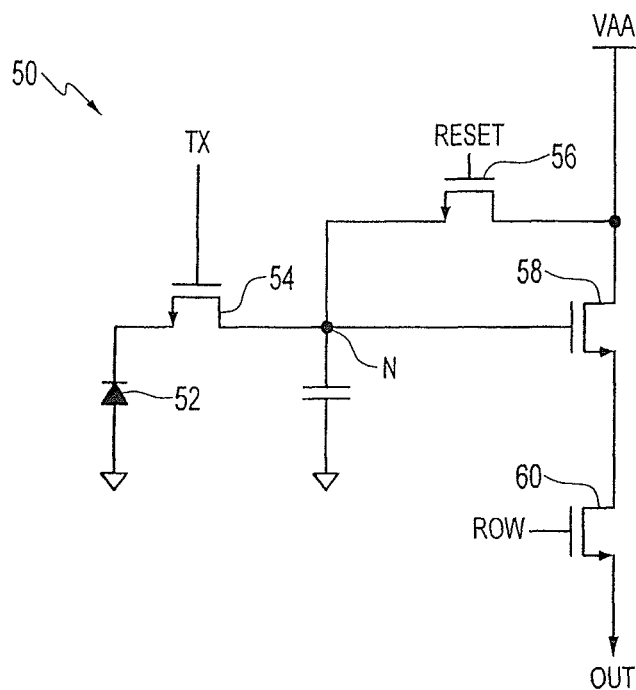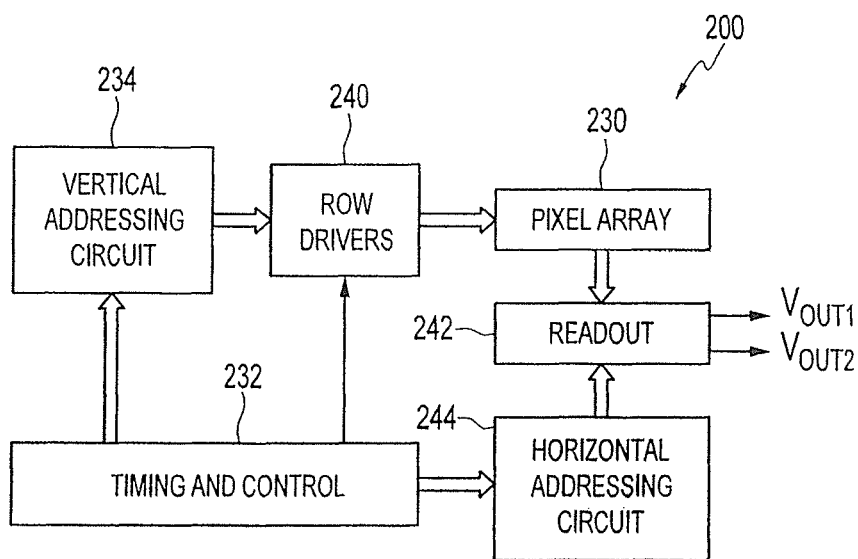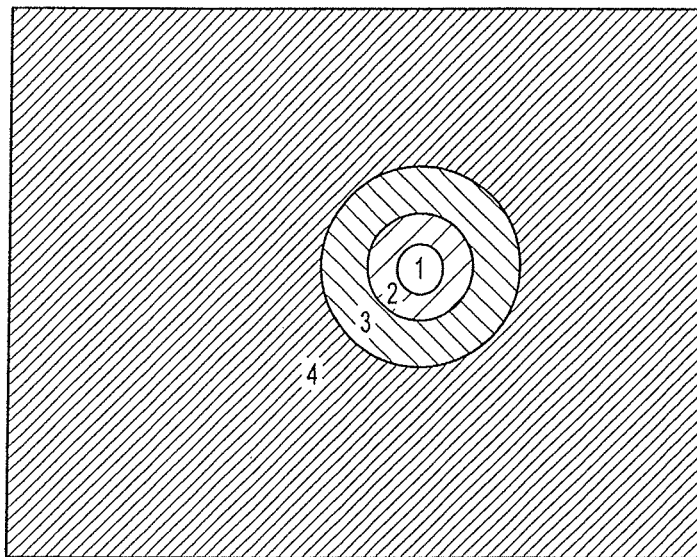
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VAA

50

TX

RESET   56

54

58

N

52

ROW   60

OUT

FIG. 1
(PRIOR ART)

200

234   240   230

VERTICAL
ADDRESSING
CIRCUIT

ROW
DRIVERS

PIXEL ARRAY

242   READOUT V_{OUT1}
V_{OUT2}

232

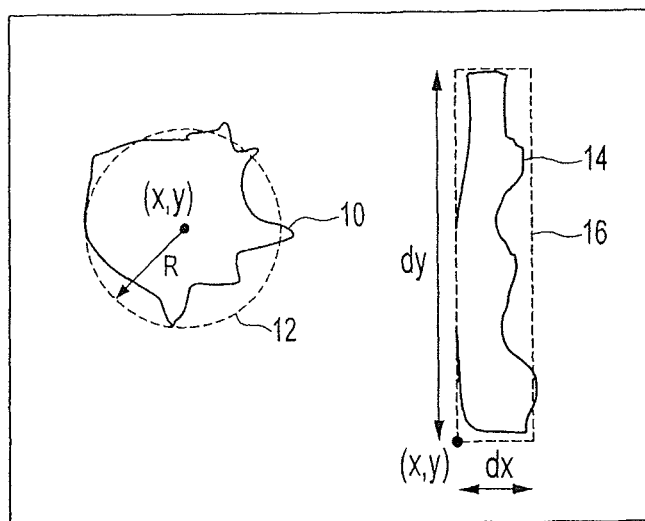244

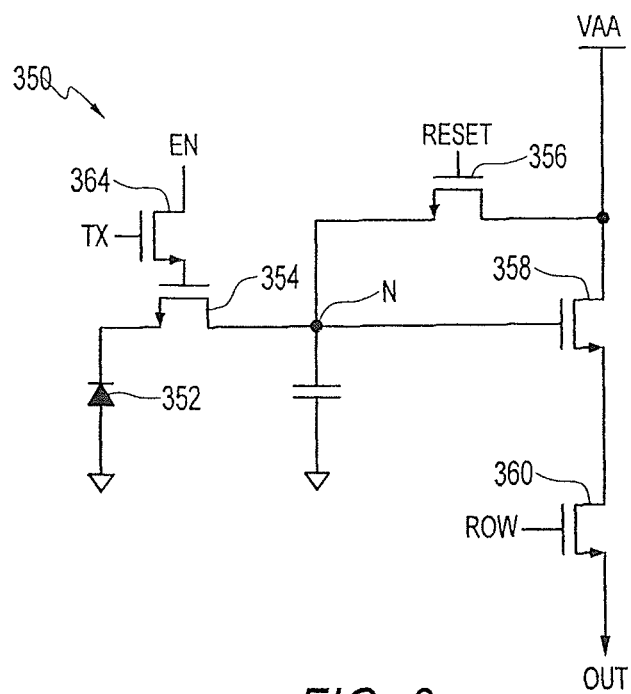TIMING AND CONTROL

HORIZONTAL
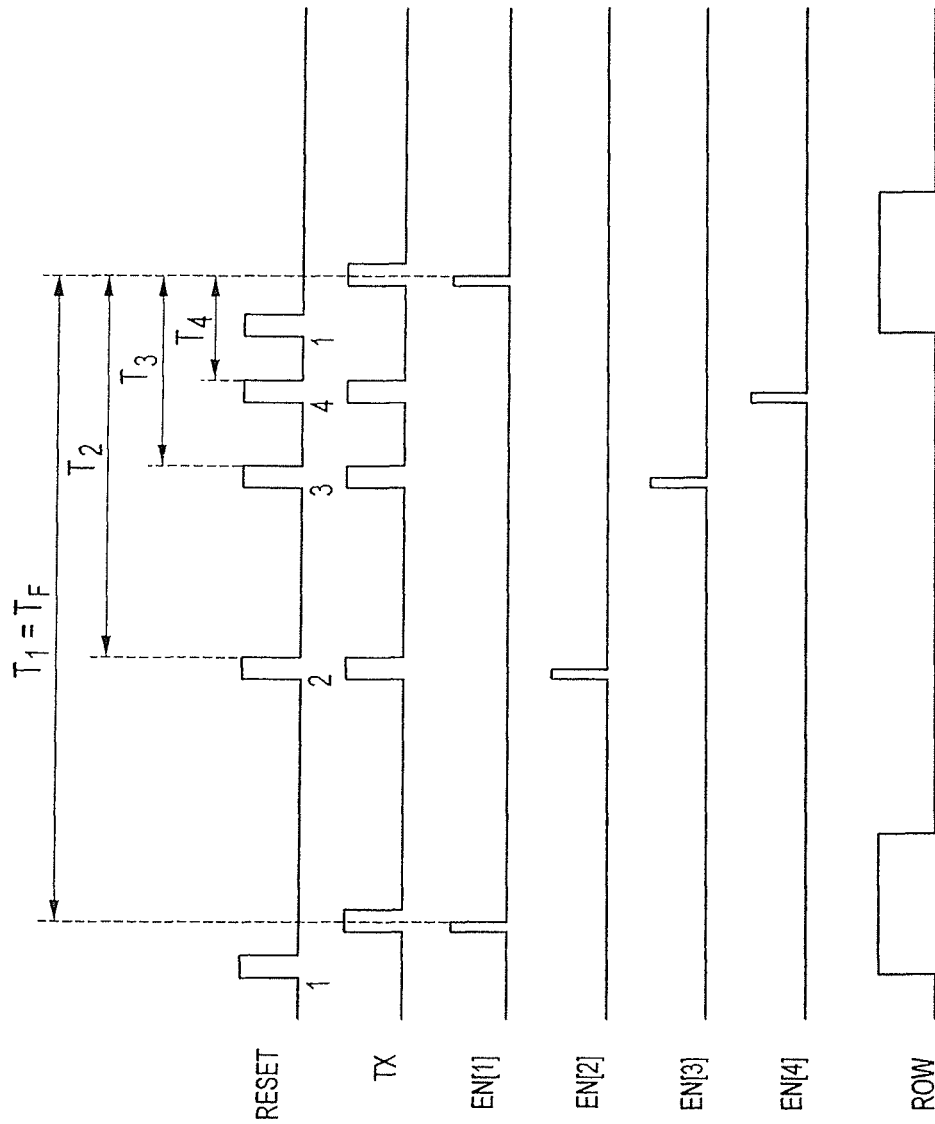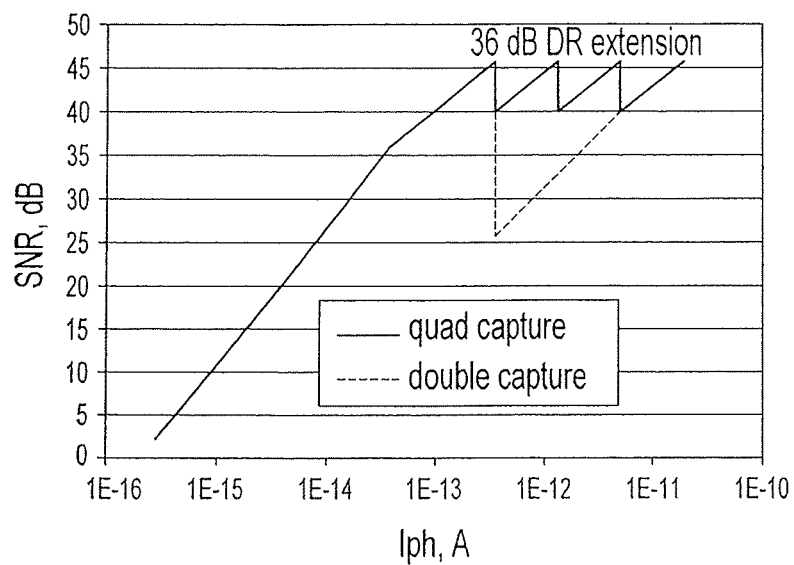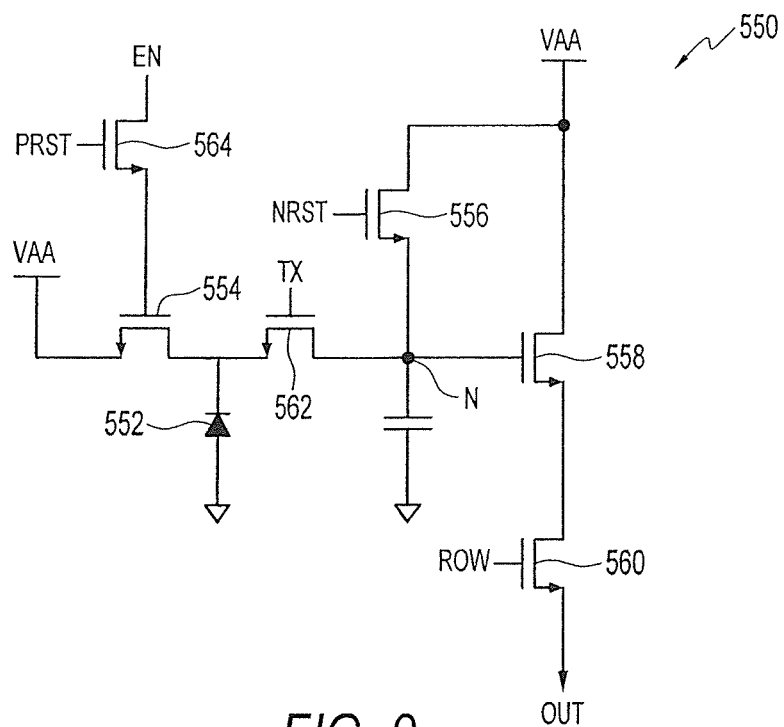ADDRESSING
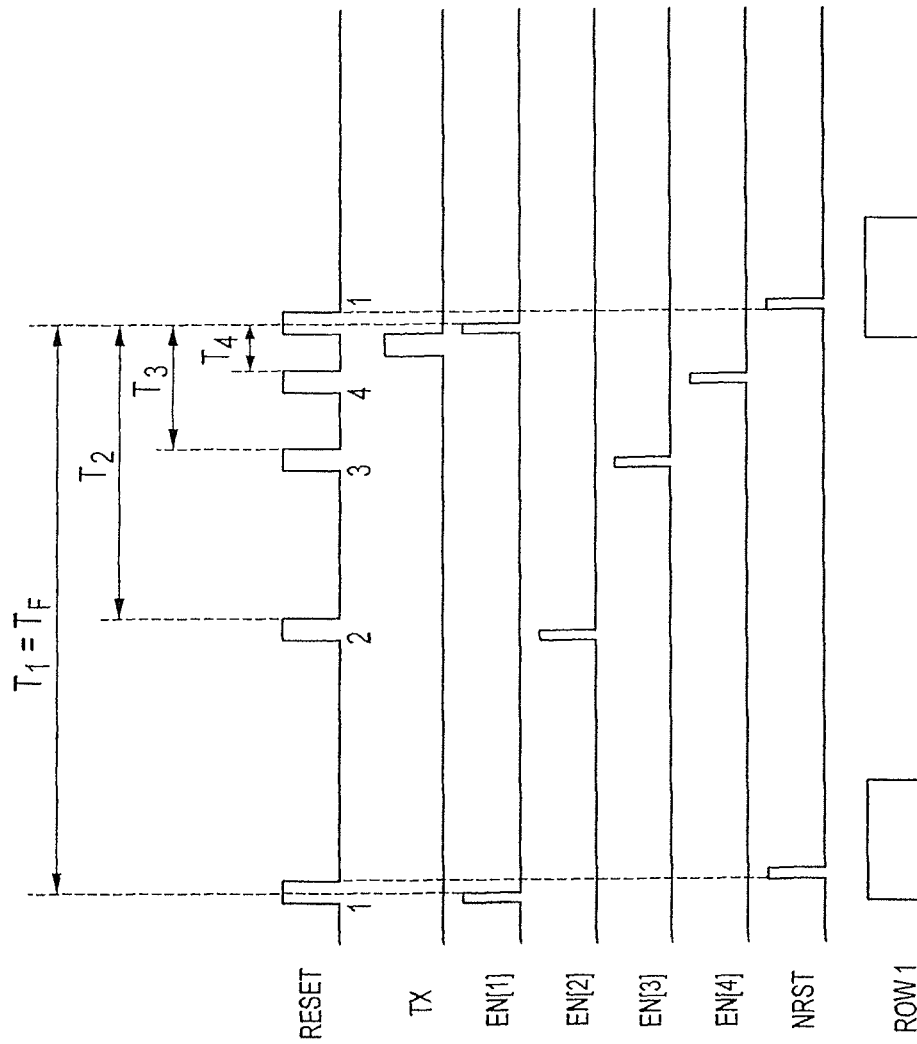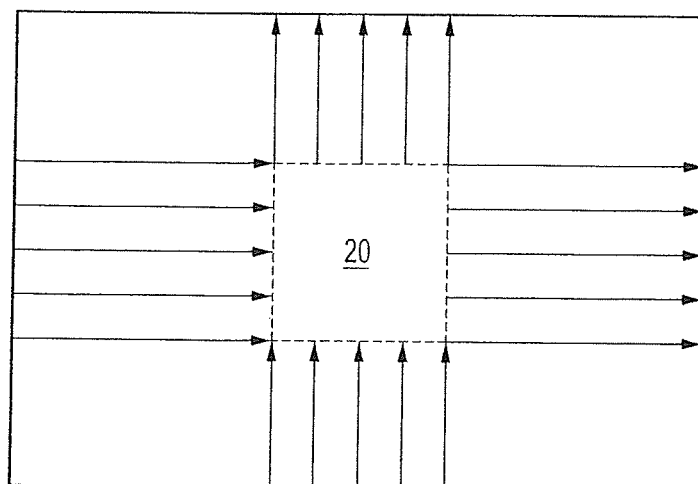CIRCUIT

FIG. 2
(PRIOR ART)

FIG. 3
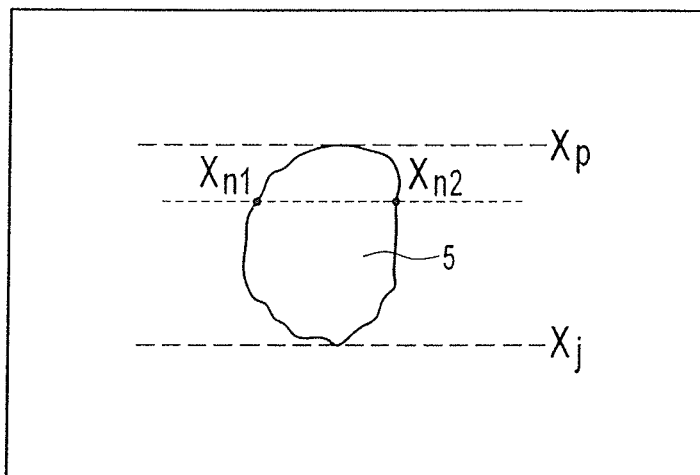
FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

FIG. 10

FIG. 11

FIG. 12

EN1

TX1 ⊣[764

752 ⊳ 754

EN2

TX2 ⊣[765

753 ⊳ 755
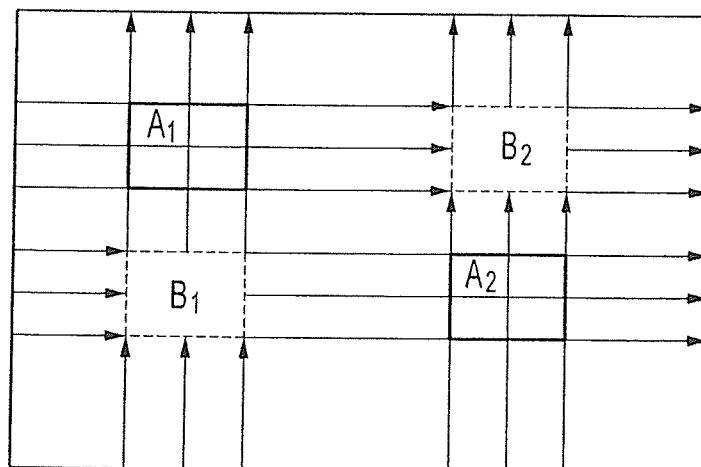
VAA

750

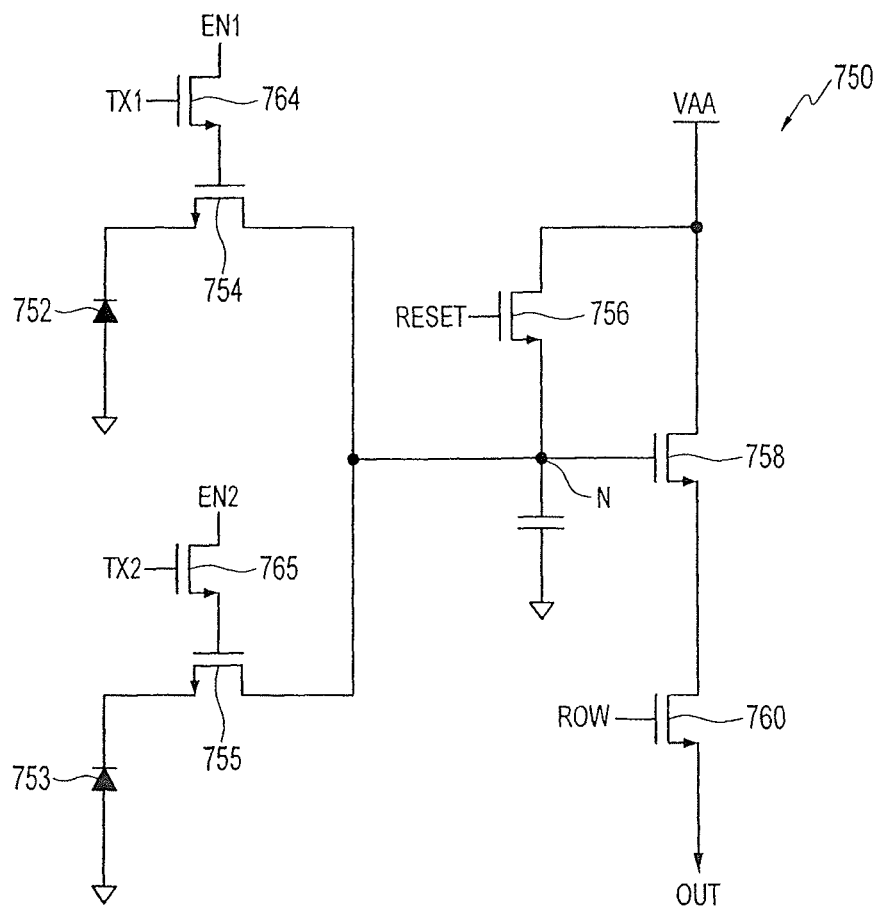RESET ⊣[756

N ⊣[758

ROW ⊣[760
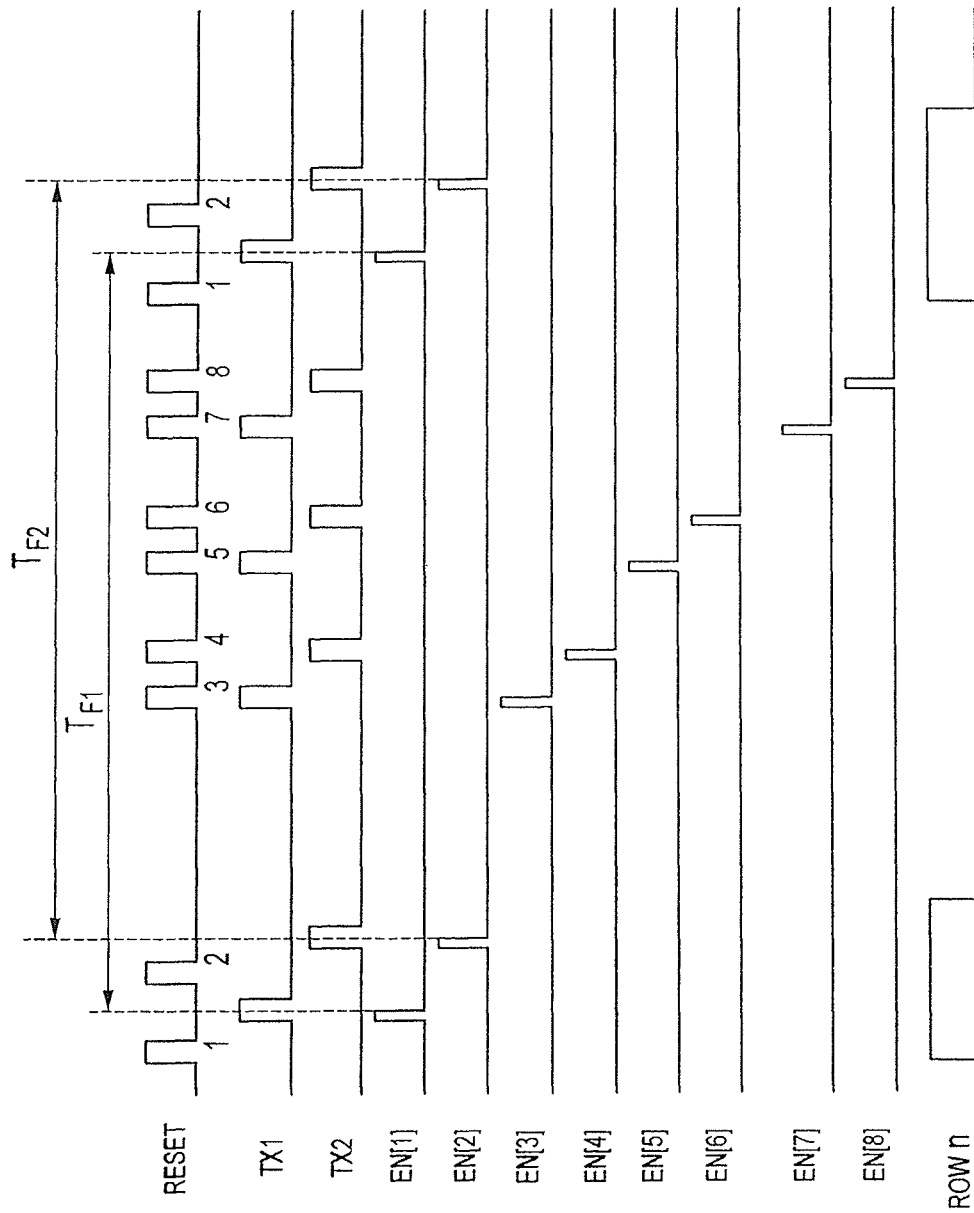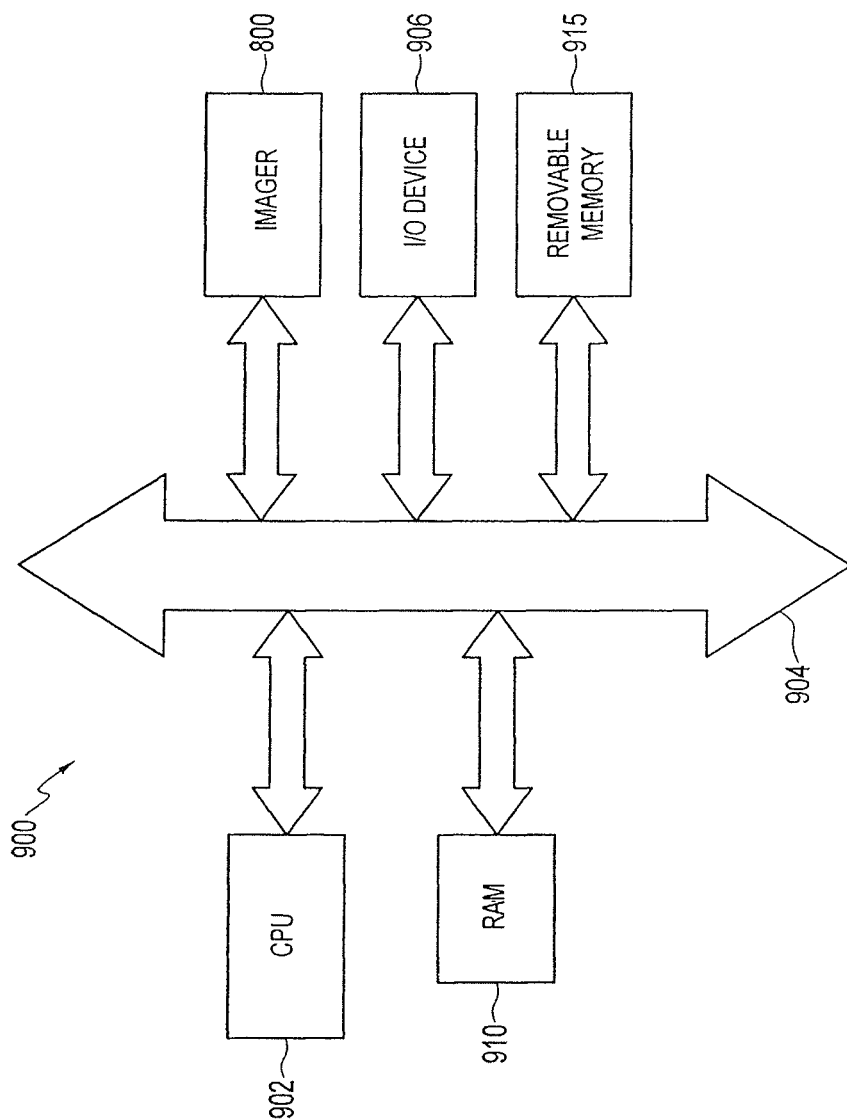
OUT

FIG. 13

FIG. 14

FIG. 15

METHOD, APPARATUS, AND SYSTEM PROVIDING AN IMAGER WITH PIXELS HAVING EXTENDED DYNAMIC RANGE

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/112,912, filed May 20, 2011, which is a divisional of U.S. patent application Ser. No. 11/509,710, filed Aug. 25, 2006, now U.S. Pat. No. 7,969,490. The entirety of each of these applications and patents is hereby incorporated by reference herein.

FIELD OF THE INVENTION

The various embodiments relate generally to imagers, and more particularly to an image that includes a pixel with extended dynamic range.

BACKGROUND

Imagers, such as complementary metal oxide semiconductor (CMOS) imagers, are commonly used in photo-imaging applications. A typical imager includes a focal plane array of pixels. Each of the cells includes a photoconversion device or photosensor such as, for example, a photogate, photoconductor, or photodiode, for generating and accumulating photo-generated charge in a portion of the substrate of the array. A readout circuit is connected to each pixel and includes at least an output transistor, which receives photo-generated charges from a doped diffusion region and produces an output signal that is read-out through a pixel access transistor.

CMOS imaging circuits, processing steps thereof, and detailed descriptions of the functions of various CMOS elements of an imaging circuit are described, for example, in U.S. Pat. Nos. 6,140,630, 6,376,868, 6,310,366, 6,326,652, 6,204,524, and 6,333,205, all of which are assigned to Micron Technology, Inc. The disclosures of each of the forgoing are hereby incorporated by reference herein in their entirety.

FIG. 1 illustrates a typical four transistor pixel 50 utilized in an imager, such as a CMOS imager. The pixel 50 includes a photosensor 52 (e.g., photodiode, photogate, etc.), a storage node configured as a floating diffusion region N, transfer transistor 54, reset transistor 56, source follower transistor 58 and row select transistor 60. The photosensor 52 is connected to the floating diffusion region N by the transfer transistor 54 when the transfer transistor 54 is activated by a transfer control signal TX. The reset transistor 56 is connected between the floating diffusion region N and an array pixel supply voltage VAA. A reset control signal RESET is used to activate the reset transistor 56, which resets the floating diffusion region N to a known state as is known in the art.

The source follower transistor 58 has its gate connected to the floating diffusion region N and is connected between the array pixel supply voltage VAA and the row select transistor 60. The source follower transistor 58 converts the charge stored at the floating diffusion region N into an electrical output voltage signal. The row select transistor 60 is controllable by a row select signal ROW for selectively outputting the output voltage signal OUT from the source follower transistor 58. For each pixel 50, two output signals are conventionally generated, one being a reset signal V_{rst} generated after the floating diffusion region N is read, the other being an image signal V_{sig} generated after charges are transferred from the photosensor 52 to the floating diffusion region N.

FIG. 2 shows an imager 200 that includes an array 230 of pixels (such as the pixel 50 illustrated in FIG. 1) and a timing

and control circuit 232. The timing and control circuit 232 provides timing and control signals for enabling the reading out of signals from pixels of the array 230 in a manner commonly known to those skilled in the art. The array 230 has dimensions of M rows by N columns of pixels, with the size of the array 230 depending on a particular application.

Signals from the imager 200 are typically read out a row at a time using a column parallel readout architecture. The timing and control circuit 232 selects a particular row of pixels in the array 230 by controlling the operation of a row addressing circuit 234 and row drivers 240. Signals stored in the selected row of pixels are provided to a readout circuit 242 in the manner described above. The signal read from each of the columns is then read out sequentially using a column addressing circuit 244. Differential pixel signals (Vrst, Vsig) corresponding to the pixel reset signal and image pixel signal are provided as respective outputs V_{out1}, V_{out2} of the readout circuit 242.

The pixels 50, of pixel array 230, have a characteristic dynamic range. Dynamic range refers to the range of incident light that can be accommodated by a pixel in a single image frame. It is desirable to have pixels with a high dynamic range to image scenes that generate high dynamic range incident signals, such as indoor rooms with windows to the outside, outdoor scenes with mixed shadows and bright sunshine, and night-time scenes combining artificial lighting and shadows.

The dynamic range for a pixel is commonly defined as the ratio of its largest non-saturating signal to the standard deviation of its noise under dark conditions. The dynamic range is limited on an upper end by the charge saturation level of the pixel photosensor, and on a lower end by noise imposed limitations and/or quantization limits of the analog-to-digital converter used to produce a digital signal from analog pixel signals. When the dynamic range of a pixel is too small to accommodate the variations in light intensities of the imaged scene, e.g. by having a low saturation level, image distortion occurs.

One approach to increasing dynamic range is to provide structures to increase dynamic range, which includes structures for signal companding, multiple signal storage, and signal controlled reset. Companding involves compressing and subsequently expanding a signal to increase the dynamic range, but suffers from drawbacks such as requiring a non-linear output that hampers subsequent processing and causes increased pixel fixed pattern noise (FPN), a dip in the signal to noise ratio (SNR) at the knee point, and low contrast at high brightness. Structures providing multiple signal storage and signal controlled reset may not be practical because they require an increase in die area due to additional column circuitry.

Another approach to increase dynamic range is to use multiple image captures with different integration times. Dual capture, for example, is relatively simple to implement, but suffers from an SNR dip at the knee point of the collected charge relative to output signal. A multiple capture approach that requires more than two image captures is quite difficult to implement and requires high speed non-destructive readout along with on-chip memory and additional column circuitry.

BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. 1 shows a portion of a conventional imager;

FIG. 2 is a block diagram of a conventional imager;

FIG. 3 shows pixels divided into brightness zones according to an embodiment;

FIG. 4 shows a zone bounded by various coordinates according to an embodiment;

FIG. **5** shows zones having complex shapes that may be approximated by shapes according to an embodiment;

FIG. **6** shows a portion of an imager constructed in accordance with an embodiment;

FIG. **7** is a timing diagram for operations of the imager shown in FIG. **6**;

FIG. **8** is a graph of signal to noise ratio versus photocurrent for dual sampling and quadruple sampling operations according to embodiments;

FIG. **9** shows a portion of an imager constructed in accordance with another embodiment;

FIG. **10** is a timing diagram for operations of the imager shown in FIG. **9**;

FIG. **11** shows a global shutter sensor window;

FIG. **12** shows selected brightness zones and generated false brightness zones according to an embodiment;

FIG. **13** shows a portion of a shared pixel imager constructed in accordance with an embodiment;

FIG. **14** is a timing diagram for operations of the imager shown in FIG. **13**; and

FIG. **15** illustrates a system suitable for use with any one of the embodiments.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description, reference is made to the accompanying drawings, which are a part of the specification, and in which is shown by way of illustration various embodiments whereby the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to make and use the invention. It is to be understood that other embodiments may be utilized, and that structural, logical, and electrical changes, as well as changes in the materials used, may be made without departing from the spirit and scope of the present invention.

The term "pixel" refers to a picture element unit cell containing a photosensor and transistors for converting light radiation to an electrical signal. For purposes of illustration, a representative pixel is illustrated in the figures and description herein and, typically, fabrication of all pixels in an imager will proceed simultaneously in a similar fashion.

Although various embodiments are described herein with reference to the architecture of one pixel, it should be understood that this is representative of a plurality of pixels in an array of an imager. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the invention is defined only by the appended claims.

The disclosed embodiments increase the dynamic range of an imager using multiple pixel resets to reset the accumulated charge on the pixel photosensor. The accumulated charge in the photosensor is reset at varying times during a frame time depending on the light intensity that the pixel will be exposed to during the frame time. Pixels that will be exposed to high light intensity are reset later in the frame than pixels that will be exposed to lower light intensity. This reduces the value of the pixel image signal produced by pixels exposed to high light intensity relative to pixels exposed to low light intensity and increases the dynamic range as the pixel image signal exposed to high light intensity can be expanded during digital signal processing.

The light intensity that the pixels will be exposed to during the frame time is initially determined. This may be accomplished using the same latency approach as is used in automatic exposure techniques, which are known in the art. The light intensity that each pixel in the array will be exposed to may be mapped together with the automatic exposure technique using the image processor or a camera processor.

Preset thresholds of light intensity are used to designate a plurality of light intensity ranges. Each light intensity range is associated with a brightness value. The light intensity may be divided into two, three, four, or more ranges. Each pixel exposed to light intensity falling into a range is assigned the brightness value associated with that range and that value is associated with a time of application of a photosensor reset signal for the pixel.

In one embodiment, the brightness value for each pixel is stored to memory. In another embodiment, to save memory, pixels having the same brightness value may be grouped into zones of pixels and the dimensions of the zones may be stored to memory. FIG. **3**, for example, shows an image field, divided into four brightness zones, **1**, **2**, **3**, and **4** in which the corresponding pixels (not shown) may be grouped. Each of the four zones, **1**, **2**, **3**, and **4**, may therefore be made up of pixels assigned with the same brightness value.

FIG. **4**, for example, shows one zone **5** of same brightness value pixels in which the nth row of pixels is bounded on the left by the coordinate X_{n1} and on the right by the coordinate X_{n2}. The zone is bounded on the top by row "p" and at the bottom by row "j". Therefore, rather than storing the same brightness value for each pixel in the zone, two horizontal coordinates for each row and two vertical coordinates for the entire brightness zone can be saved to memory, thus reducing the size of the required memory.

In another embodiment, to save memory, brightness zones with the same brightness value but having complex shapes may be approximated by one or more shapes having easily defined areas, such as circles, rectangles, ovals, triangles, annular rings, and others. FIG. **5**, for example, shows a complex shape **10**, that may be approximated by a circle **12**. The area of the circle **12** may be saved to memory by saving the "x" and "y" coordinates of the center of the circle and the radius R of the circle. FIG. **5** also shows another complex shape **14** that may be approximated by a rectangle **16**. The area of the rectangle may be saved to memory by saving the "x" and "y" coordinates of one corner of the rectangle and the length dy and width dx of the rectangle.

Once a brightness value has been assigned to each pixel and the values have been stored to memory either directly or as zone coordinates, the array of pixels may be operated to capture an image. FIG. **6** shows a pixel **350** for use in a rolling shutter imager constructed in accordance with an embodiment of the invention. The pixel **350** includes a photosensor **352** (e.g., photodiode, photogate, etc.), floating diffusion region N for storing charge, transfer transistor **354**, reset transistor **356**, source follower transistor **358**, row select transistor **360**, and photosensor reset transistor **364**. The drain of the transfer transistor **354** is connected to the photosensor **352**. The source of the transfer transistor **354** is connected to the floating diffusion region N. The source of the photosensor reset transistor **364** is connected to the gate of the transfer transistor **354**. The source of the reset transistor **356** is connected to the floating diffusion region N. The drain of the reset transistor **356** is connected to the supply voltage VAA. The gate of the source follower transistor **358** is connected to the floating diffusion region N. The drain of the source follower transistor **358** is connected to the supply voltage VAA. The source of the source follower transistor **358** is connected to the drain of the row select transistor **360**. An enable signal EN is applied to the drain of the photosensor reset transistor **364**. A transfer control signal TX is applied to the gate of the photosensor reset transistor **364**. A reset control signal RESET is applied to the gate of the reset transistor **356**. A row select signal ROW is applied to the gate of the row select transistor **360**.

FIG. **7** is an example of a timing diagram which may be used to operate the rolling shutter sensor pixel **350** of FIG. **6**. The operation of the pixel **350** is now described with reference to FIGS. **6** and **7**.

The reset control signal RESET is pulsed once during each frame time T_F for each brightness value that may be assigned to each pixel. In this embodiment, four brightness values are used, and therefore, four reset control signals $RESET_1$, $RESET_2$, $RESET_3$, $RESET_4$ will be pulsed during the frame time T_F.

The transfer control signal TX is pulsed and applied to the photosensor reset transistor **364** at the same time as the reset control signals $RESET_2$, $RESET_3$, $RESET_4$ to turn on transfer gate **354** when an enable signal EN is present at the photosensor reset transistor **364**, and thus reach the photosensor while the reset transistor **356** is on. The transfer control signal TX activates the photosensor reset transistor **364**.

Depending on the brightness value assigned to the pixel **350**, a dedicated column controller pulses an enable signal EN[**2**], EN[**3**], or EN[**4**] during the pulsing of one of the reset control signals $RESET_2$, $RESET_3$, $RESET_4$ and transfer control signals TX. The enable signal EN[**2**], EN[**3**], or EN[**4**] activates the transfer transistor **354** to transfer any accumulated charge from the photosensor **352** to the floating diffusion region N, which is then under reset, and thus resets the photosensor **352** to restart charge integration. The enable signal EN[**1**], EN[**2**], EN[**3**], or EN[**4**] pulse should be shorter than the transfer control signal TX pulse to ensure that the transfer gate transistor **354** is completely off before the reset control signal RESET resets the floating diffusion region N, which discards the charge transferred from the photosensor **352**. This ensures that the transfer transistor **354** is completely off during charge integration.

If the brightness value assigned to the pixel **350** is low, the pixel **350** will receive only the first enable signal EN1 to reset and read out the charge on the photosensor **352** at the end of the frame time T_F so that the photosensor **352** may accumulate charge over a first integration time T_1, which is equal to the entire frame time T_F. Regardless of the brightness value assigned, each pixel at least receives the first enable signal EN[**1**] during each frame time T_F to reset and read out the charge on the photosensor **352**. If the brightness value assigned to the pixel **350** is of a lower intermediate value, the pixel **350** will receive the second enable signal EN[**2**] to reset the photosensor near the middle of the frame time T_F so that the photosensor **352** will accumulate charge over a shorter integration time T_2. If the brightness value assigned to the pixel **350** is of a higher intermediate value, the pixel **350** will receive the third enable signal EN[**3**] to reset the photosensor towards the end of the frame time T_F so that the photosensor **352** will accumulate charge over an even shorter integration time T_3. If the brightness value assigned to the pixel **350** is high, the pixel **350** will receive the fourth enable signal EN[**4**] to reset the photosensor **352** near the end of the frame time T_F, so that the photosensor **352** will accumulate charge over the shortest integration time T_4.

Pixel reset occurs at the end of the frame time T_F for a given row. The reset control signal RESET is pulsed at $RESET_1$ to the gate of the reset transistor **356** to reset the floating diffusion region N. The pixel reset signal V_{rst} is sampled during $RESET_1$ by applying the charge on the floating diffusion region to the gate of the source follower transistor **358** to generate the pixel reset signal V_{rst}. A row select signal ROW is applied to the row select transistor **360** to output the pixel reset signal V_{rst}. The pixel reset signal V_{rst} is then stored by column readout circuitry (not shown) connected to a column line, which is connected to the pixel **350**.

After this, the transfer control signal TX and the enable signal EN[**1**] are pulsed to transfer any charge accumulated from the photosensor **352** to the floating diffusion region N. The charge on the floating diffusion region N is applied to the gate of the source follower transistor **358** to generate the pixel image signal V_{sig}. The row select signal ROW is applied to the row select transistor **360** to output the pixel image signal V_{sig}. The pixel image signal V_{sig} is stored in column circuits (not shown) connected to the column line, which is connected to pixel **350**. The next integration period for pixels in a given row starts when EN[**1**] is off.

The pixel reset signal V_{rst} and the pixel image signal V_{sig} are then subtracted to produce a differential signal and the differential signal is digitized and sent to an image processor. The gain of the digital signal is then adjusted by the image processor using a value that correlates to the brightness value to represent the actual light intensity to which the pixel **350** was exposed.

The floating diffusion region N may therefore store similar amounts of charge and cause the source follower transistor **358** to produce pixel image signals V_{sig} with similar values regardless of whether the pixel is exposed to low light, intermediate light, or bright light. Also, resetting the charge at varying times may prevent the floating diffusion region N from becoming saturated and may thus prevent blooming.

Each of the four zones, **1**, **2**, **3**, and **4**, shown in FIG. **2** is made up of pixels assigned with the same brightness value, and therefore, every pixel in a particular zone should be exposed to a light intensity that falls within the light intensity thresholds of the light intensity range assigned to that zone. The light intensity range should correspond to the saturation level for a given integration time, where the integration time is fixed by the enable signal EN sent to the pixels. Using more zones, e.g. using more, smaller light intensity ranges and more integration times, results in less SNR dip. The SNR dip when the integration time is switched from T_1 to T_2 is calculated by the equation:

$$SNR_{dip} = 10 * \log(T_1/T_2)$$

FIG. **8** shows SNR versus photocurrent when using two zones for dual sampling **802** and four zones for quadruple sampling **804**. It can be seen from FIG. **8** that dual sampling **802** causes SNR to drop 20 dB with 36 dB DR extension. The quadruple sampling **804** causes SNR to drop only 5 dB with the same 36 dB DR extension. As is apparent from the foregoing discussion, although one embodiment has been described in which four brightness values and four associated photosensor reset signals EN[**1**], EN[**2**], EN[**3**], EN[**4**] are employed, a larger or smaller number of brightness levels and associated reset signals may be employed in any of the described embodiments.

FIG. **9** shows a global shutter pixel **550** for use in an imager constructed in accordance with another embodiment. The pixel **550** includes a photosensor **552** (e.g., photodiode, photogate, etc.), a floating diffusion region N, an anti-blooming transistor **554**, a reset transistor **556**, a source follower transistor **558**, a row select transistor **560**, a transfer transistor **562**, and a photosensor reset transistor **564**. The photosensor **552** is connected to the drain of the anti-blooming transistor **554** and the drain of the transfer transistor **562**. The gate of the anti-blooming transistor **554** is connected to the source of the photosensor reset transistor **564**. The source of the anti-blooming transistor **554** is connected to the supply voltage VAA. The source of the photosensor reset transistor **562** is connected to the floating diffusion region N. The source of the reset transistor **556** is connected to the floating diffusion region N. The drain of the reset transistor **556** is connected to

the supply voltage VAA. The gate of the source follower transistor **558** is connected to the floating diffusion region N. The drain of the source follower transistor **558** is connected to the supply voltage VAA. The source of the source follower transistor **558** is connected to the drain of the row select transistor **560**. An enable signal EN is applied to the drain of the photosensor reset transistor **564**. A transfer control signal TX is applied to the gate of the photosensor reset transistor **562**. A floating diffusion reset control signal NRST is applied to the gate of the reset transistor **556**. A photosensor reset control signal PRST is applied to the gate of the photosensor reset transistor. A row select signal ROW is applied to the gate of the row select transistor **560**.

FIG. **10** is a timing diagram illustrating the timing of the signals to operate the pixel **550** of FIG. **9**. The operation of the pixel **550** is now described with reference to FIGS. **9** and **10**.

The pixel **550** is assigned a brightness value and the brightness value is stored to memory as described above. In the illustrated embodiment, the pixel **550** is assigned one of four brightness values.

A photosensor reset control signal PRST is pulsed four times (once for each of four brightness values that may be assigned) and applied to the gate of the photosensor reset transistor **564**.

A dedicated column controller pulses a first enable signal EN[**1**] during the first photosensor reset control signal $PRST_1$ pulse and, depending on the brightness value assigned to the pixel **550**, may pulse another enable signal EN[**2**], EN[**3**], or EN[**4**] during the pulsing of one of the second $PRST_2$, third $PRST_3$, or fourth $PRST_4$ photosensor reset control signal PRST pulses, respectively. The enable signal EN[**1**], EN[**2**], EN[**3**], or EN[**4**] and read signal PRST activate the anti-blooming transistor **554** to reset the charge on the photosensor **552**. The enable signal EN[**1**], EN[**2**], EN[**3**], or EN[**4**] pulse should be shorter than the photosensor reset control signal PRST pulse to ensure that the anti-blooming transistor **554** is completely off before charge integration begins.

Similarly to the embodiment described above, the pixel **550** will receive the first enable signal EN[**1**], and based on the assigned brightness value, may receive a second enable signal EN[**2**], third enable signal EN[**3**], or fourth enable signal EN[**4**], to reset the photosensor **552** at the beginning, near the middle, towards the end, or near the end, respectively, of the frame time T_F.

At the end of the frame time T_F, the transfer control signal TX is pulsed and applied to the transfer transistor **562** to transfer any charge accumulated during the integration period from the photosensor **552** to the floating diffusion region N. The charge on the floating diffusion region N is applied to the gate of the source follower transistor **558** to generate the pixel image signal V_{sig}. The row select signal ROW is applied to the row select transistor **560** to output the pixel image signal V_{sig}. The pixel image signal V_{sig} is stored in column circuitry (not shown) connected to a column line, which is connected to the pixel **350**.

The floating diffusion region reset control signal NRST is pulsed and applied to the gate of the reset transistor **556** to reset the floating diffusion region N at the row readout time, which happens once in the frame time T_F. The charge on the floating diffusion region N is applied to the gate of the source follower transistor **558** to generate the pixel reset signal V_{rst}. A row select signal ROW is applied to the row select transistor **560** to output the pixel reset signal V_{rst}. The pixel reset signal V_{rst} is stored in column circuitry (not shown) connected to a column line, which is connected to the pixel **550**.

The pixel reset signal V_{rst} and the pixel image signal V_{sig} are then subtracted to produce a differential signal and the differential signal is digitized and sent to an image processor. The gain of the digital signal is then adjusted by the image processor using a value that correlates to the brightness value to represent the actual light intensity to which the pixel **550** was exposed.

It is desired that the dimensions of the pixel zones be rectangular when a global shutter sensor pixel is used because a global shutter sensor window is rectangular. FIG. **11** shows a global shutter sensor window **20**. Furthermore, two or more zones of the same brightness can not be selected simultaneously because this will generate false brightness zones. FIG. **12** shows a situation where brightness zones A_1 and A_2 are selected at the same time and false brightness zones B_1 and B_2 are generated. The false brightness zones B_1 and B_2 are generated because the column lines are the same for the areas A_1 and A_2 where different integration times are desirable and for areas B_1 and B_2, respectively, in which different integration times are not desirable. This situation may be corrected by using more complicated timing, by dropping the false readouts in later processing, or by adjusting the gains.

A rolling shutter sensor with shared pixel may also be constructed in accordance with an embodiment. FIG. **13** shows an example of a shared pixel **750** for use in an imager constructed in accordance with an embodiment of the invention. The pixel **750** includes a first photosensor **752** (e.g., photodiode, photogate, etc.), a second photosensor **753**, a floating diffusion region N, a reset transistor **756**, a source follower transistor **758**, a row select transistor **760**, a first transfer transistor **754**, a second transfer transistor **755**, a first photosensor reset transistor **764** and a second photosensor reset transistor **765**. The drain of the first transfer transistor **754** is connected to the first photosensor **752**. The drain of the second transfer transistor **755** is connected to the second photosensor **753**. The source of the first transfer transistor **754** is connected to the floating diffusion region N. The source of the second transfer transistor **755** is connected to the floating diffusion region N. The source of the first photosensor reset transistor **764** is connected to the gate of the first transfer transistor **754**. The source of the second photosensor reset transistor **765** is connected to the gate of the second transfer transistor **755**. The source of the reset transistor **756** is connected to the floating diffusion region N. The drain of the reset transistor **756** is connected to the supply voltage VAA. The gate of the source follower transistor **758** is connected to the floating diffusion region N. The drain of the source follower transistor **758** is connected to the supply voltage VAA. The source of the source follower transistor **758** is connected to the drain of the row select transistor **760**. A first enable signal EN1 is applied to the drain of the first photosensor reset transistor **764**. A second enable signal EN2 is applied to the drain of the second photosensor reset transistor **765**. A first transfer control signal TX1 is applied to the gate of the first photosensor reset transistor **764**. A second transfer control signal TX2 is applied to the gate of the second photosensor reset transistor **765**. A reset control signal RESET is applied to the gate of the reset transistor **756**. A row select signal ROW is applied to the gate of the row select transistor **760**. FIG. **14** is a timing diagram illustrating the timing of the signals to operate the shared rolling shutter sensor pixel **750** of FIG. **13**. The operation of the pixel **750** is now described with reference to FIGS. **13** and **14**.

The reset control signal RESET is pulsed once for each of the two frame times T_{F1} and T_{F2} for each brightness value that may be assigned to each pixel. In this embodiment, four brightness values are used, and therefore, eight reset control

signals RESET$_1$, RESET$_2$, RESET$_3$, RESET$_4$, RESET5$_5$, RESET$_6$, RESET$_7$, RESET$_8$ will be pulsed during the frame times T$_{F1}$ and T$_{F2}$.

The first transfer control signal TX1 is pulsed and applied to the first photosensor reset transistor 764 at the same time as the reset control signals RESET$_3$, RESET$_5$, RESET$_7$ to turn on the first transfer gate 754 when an enable signal EN is present at the photosensor reset transistor 764, and thus reach the first photosensor 752 while the reset transistor 756 is on. The first transfer control signal TX1 activates the first photo-sensor reset transistor 764.

Similarly, the second transfer control signal TX2 is pulsed and applied to the second photosensor reset transistor 765 at the same time as the reset control signals RESET$_4$, RESET$_6$, RESET$_8$ to turn on the second transfer gate 755 when an enable signal EN is present at the photosensor reset transistor 764, and thus reach the second photosensor 753 while the reset transistor 756 is on. The second transfer control signal TX2 activates the second photosensor reset transistor 765.

A brightness value is assigned to the first photodiode 752 and the second photodiode 753 of the pixel 750. Depending on the brightness values assigned to the first photodiode 752, a dedicated column controller pulses an enable signal EN[3], EN[5], or EN[7] during the pulsing of one of the reset control signals RESET$_3$, RESET$_5$, RESET$_7$ and first transfer control signal TX1. The enable signal EN[3], EN[5], or EN[7] acti-vates the first transfer transistor 754 to transfer any accumu-lated charge from the first photosensor 752 to the floating diffusion region N, which is then under reset, and thus resets the first photosensor 752 to restart charge integration.

The same process is conducted for the second photodiode 753, which may be assigned a brightness value different that the one assigned to the first photodiode 752. The dedicated column controller pulses an enable signal EN[4], EN[6], or EN[8] during the pulsing of one of the reset control signals RESET$_4$, RESET$_6$, RESET$_8$ and second transfer control sig-nal TX2 to reset the second photosensor 753 to restart charge integration.

Similarly to the embodiments described above, the first photosensor reset transistor 764 will receive the first enable signal EN[1], and based on the assigned brightness value, may receive a third enable signal EN[3], fifth enable signal EN[5], or seventh enable signal EN[7], to reset the first pho-tosensor 752 at the beginning, towards the middle, towards the end, or near the end, respectively, of the frame time T$_{F1}$. The second photosensor reset transistor 765 will receive the sec-ond enable signal EN[2], and based on the assigned bright-ness value, may receive a fourth enable signal EN[4], sixth enable signal EN[6], or eighth enable signal EN[8], to reset the second photosensor 753 at the beginning, near the middle, towards the end, or near the end, respectively, of the frame time T$_{F2}$.

Pixel reset occurs at the end of the frame time T$_{F1}$ for a given row. The reset control signal RESET is pulsed at RESET$_1$ to the gate of the reset transistor 756 to reset the floating diffusion region N. The first pixel reset signal V$_{rst1}$ is sampled during RESET$_1$ by applying the charge on the float-ing diffusion region to the gate of the source follower tran-sistor 758 to generate the first pixel reset signal V$_{rst1}$. A row select signal ROW is applied to the row select transistor 360 to output the first pixel reset signal V$_{rst1}$. The first pixel reset signal V$_{rst1}$ is then stored by column readout circuitry (not shown) connected to a column line, which is connected to the pixel 750.

After this, the first transfer control signal TX1 and the enable signal EN[1] are pulsed to transfer any charge accu-mulated from the first photosensor 752 to the floating diffu-

sion region N. The charge on the floating diffusion region N is applied to the gate of the source follower transistor 358 to generate the first pixel image signal V$_{sig1}$. The row select signal ROW is applied to the row select transistor 760 to output the first pixel image signal V$_{sig1}$. The first pixel image signal V$_{sig1}$ is stored in column circuits (not shown) con-nected to the column line, which is connected to pixel 750. The next integration period T$_{F1}$ for pixels in a given row starts when TX1 is off.

The first pixel reset signal V$_{rst1}$ and the first pixel image signal V$_{sig1}$ are then subtracted to produce a differential signal and the differential signal is digitized and sent to an image processor. The gain of the digital signal is then adjusted by the image processor using a value that correlates to the brightness value to represent the actual light intensity to which the first photosensor 752 was exposed.

A similar process is followed to output the second pixel reset signal V$_{rst2}$ during the second reset control signal RESET$_2$, and to output the second pixel image signal V$_{sig2}$ during the second transfer control signal TX2 and the second enable pulse EN[2] and further process the signals.

FIG. 15 shows system 900, a typical processor system modified to include an imager 800 constructed and operated in accordance with an embodiment. The imager 800 has the overall architecture illustrated in FIG. 2, but is modified to include pixel array 230. The processor system 900 is a system having digital circuits that could include image sensor devices. Without being limiting, such a system could include a computer system, camera system, scanner, machine vision, vehicle navigation, video phone, surveillance system, auto focus system, star tracker system, motion detection system, image stabilization system, and data compression system.

System 900, for example a digital still or video camera system, generally comprises a central processing unit (CPU) 902, such as a microprocessor for conducting camera func-tions, that communicates with one or more input/output (I/O) devices 906 over a bus 904. Imager 400 also communicates with the CPU 902 over the bus 904. The processor system 900 also includes random access memory (RAM) 910, and can include removable memory 915, such as flash memory, which also communicate with the CPU 902 over the bus 904. The imager 800 may be combined with the CPU processor with or without memory storage on a single integrated circuit or on a different chip than the CPU processor.

The processes and devices described above illustrate pre-ferred methods and typical devices of many that could be used and produced. However, it is not intended that the present invention be strictly limited to the above-described and illus-trated embodiments. Any modification, though presently unforeseeable, of the present invention that comes within the spirit and scope of the following claims should be considered part of the present invention.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A method of operating an imager array containing a plurality of pixels, each having an associated photosensor, the method comprising:

determining for each of the pixels of the array an associated light intensity that the pixel photosensor will be exposed to during an image capture period;

assigning to each pixel one of a plurality of brightness values, each brightness value being associated with a different pixel photosensor reset timing; and

accumulating in the photosensor of each pixel a light inten-sity value during the image capture period and using a photosensor reset timing associated with an assigned pixel brightness value of each pixel to reset the accumu-

lated light intensity value of the photosensor of each pixel during the image capture period,

wherein each pixel comprises a floating diffusion region for receiving charge from a photosensor through a transfer transistor, a reset transistor for resetting charge on the floating diffusion region and a photosensor reset transistor for controlling operation of the transfer transistor, the method further comprising operating the reset transistor with reset control signals to reset the floating diffusion region a plurality of times during the image capture period and operating the photosensor reset transistor to control operation of the transfer transistor such that the photosensor is reset during the image capture period by connection to the floating diffusion region at a time corresponding to a reset of the floating diffusion region by the reset transistor.

2. A method as in claim **1**, further comprising storing the brightness value assigned to each pixel of the array in memory.

3. A method as in claim **1**, further comprising grouping pixels having the same brightness value into brightness zones and storing coordinates of the brightness zones in memory.

4. A method as in claim **3**, wherein a zone having a complex shape is approximated by a shape having one of a plurality of predefined areas.

5. A method as in claim **4**, wherein the predefined areas include circles, rectangles, ovals, triangles, and annular shapes.

6. A method as in claim **2**, wherein different pixel reset timings are such that pixels having a higher brightness value have their photosensors reset later in time in the image capture period than pixels having a lower brightness value.

7. A method as in claim **1**, wherein each different photosensor reset timing has an associated time of application of a pixel photosensor reset signal during the image capture period.

8. A method as in claim **1**, wherein each pixel photosensor of the array is reset at least once at the end of an image capture period and pixels of the array which have brightness values above a lowermost brightness value also have their photosensors reset during the image capture period at a reset timing associated with the assigned pixel brightness value.

9. A method as in claim **1**, wherein the different photosensor reset timings are arranged to establish a plurality of integration periods during an image capture period corresponding to the plurality of brightness values which can be assigned to a pixel.

10. A method as in claim **1**, wherein the photosensor reset transistor operates the transfer transistor at the end of the

image capture period and during a time when the floating diffusion region is not being reset by the reset transistor to produce a pixel output signal at the floating diffusion region.

11. A method as in claim **1**, wherein a plurality of pixels share a common floating diffusion region and reset transistors.

12. A method as in claim **1**, wherein the photosensor reset transistor is operative in response to a first control signal and a second control signal and wherein the first and second control signals are applied during operation of the reset transistor and during the image capture period to reset the photosensor at a timing corresponding to the assigned pixel brightness value.

13. A method as in claim **1**, wherein the number of brightness values is four.

14. A method of operating an imager array containing a plurality of pixels, each having an associated photosensor, the method comprising:

determining for each of the pixels of the array an associated light intensity that the pixel photosensor will be exposed to during an image capture period;

assigning to each pixel one of a plurality of brightness values, each brightness value being associated with a different pixel photosensor reset timing; and

accumulating in the photosensor of each pixel a light intensity value during the image capture period and using a photosensor reset timing associated with an assigned pixel brightness value of each pixel to reset the accumulated light intensity value of the photosensor of each pixel during the image capture period,

wherein each pixel comprises a floating diffusion region for receiving charge from a photosensor through a transfer transistor, a reset transistor for resetting charge on the floating diffusion region, a transistor for draining charge from the photosensor, and a photosensor reset control transistor for controlling operation of the charge draining transistor, the method further comprising operating the photosensor reset transistor during the image capture period to turn on the charge draining transistor at a timing corresponding to a brightness value associated with the pixel to thereby reset the photosensor during the image capture period.

15. A method as in claim **14**, wherein the photosensor reset transistor is operative in response to a first control signal and a second control signal and the first and second control signals are applied during the image capture period to reset the photosensor at a timing corresponding to the assigned pixel brightness value.

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